FUNDAMENTAL MODE FREQUENCY OF THE STORAGE RING SINGLE CELL CAVITY

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The fundamental mode frequency of the prototype storage ring cavity has been measured with various port terminations and cavity temperatures. Since the highest tuned frequency of the prototype cavity with a tuner under the high RF power test condition is measured to be lower than the system specified frequency, a slight dimensional change in the cavity design is required for manufacturing future cavities. In addition to this, an extra dimensional correction is required to compensate the volume changes due to the tuner position and increased port sizes. In the following, the measured frequencies and the estimated frequency shift due to the volume changes are discussed. The correction to the internal dimension of the new cavity design based on the estimated frequency shift is also discussed.

I. Frequency Measurement Data

Measured frequencies of the prototype single cell cavity with various port terminations are as follows:

(a) All four big ports are plugged. The plugs are flush to the cavity inner surface. Frequency is 352.60 *MHz*.

(b) Four ports are terminated with a loop coupler, one tuner and two plates. The loop coupler is adjusted for matched input and then terminated with a matched load. The tuner is adjusted for the frequency of 351.93 *MHz*.

(c) Frequency is measured under the high power test condition with vacuum ($\sim$1 x 10^{-8}*torr*), higher cavity temperature ($\sim$ 100°F), and other accessories such as a tuner, two turbo pumps, and an $E - probe$ damper, which is close to the actual operating condition. With maximum insertion of the tuning plunger, the resonant frequency is measured as f_m = 351.60 *MHz*. In this measurement the small ports in the cavity covers are covered with blank flanges.

The measurement in case (c) is considered to be the most practical and useful in determining the right cavity dimensions for the right frequency. This information is used in estimation of the resonant frequency changes and the corresponding dimensional correction of the cavity.

II. Estimation of Frequency

A frequency perturbation coefficient C may relate the frequency and the volume change as

$$\frac{\Delta\omega}{\Delta_o} = C\frac{\Delta\tau}{\tau}$$

where τ is the volume of the cavity and $\Delta\tau$ is the volume change. Using the measurement data of the 510 *MHz* cavity with a 70 *mm* diameter plunger tuner [1], the frequency change $\Delta f/f = 1.75$ *MHz* if the plunger is pushed into the cavity a distance of 50 *mm* and $\Delta f/f = 0.18$ *MHz* if the plunger is pulled out from the cavity by 20 *mm*. The volume perturbation due to insertion of the plunger is estimated to be $\Delta v/v = 4.99 \times 10^{-3}$ for [1] and $\Delta v/v = 4.47 \times 10^{-3}$ for the APS single cell cavity. This information is used to find the equivalent tuning range of the 352 *MHz* single cell cavity and its 115 *mm* diameter tuner. The estimated frequency effect of the tuner is shown in Figure 1. The maximum tuning range of the 352 *MHz* tuner is estimated as $(\Delta f)^t = 1.56$ *MHz* for 50 *mm* of inward travel and 0.17 *MHz* for 20 *mm* of outward travel. This can be translated into an inward perturbation coefficient $C^i = 0.99$ and an outward perturbation coefficient $C^o = -0.26$, to be used in (1). These values are similar to the results reported in [2].

In each cover, there are sixteen small ports in two circular arrays. Each array has eight uniformly spaced ports. One array is close to the nose cone and the other is close to the rim. The eight small ports close to the rim will have much stronger interaction with the fundamental mode fields than with the ports close to the nose cone. Thus, the effects of the small ports close to the nose cones will be ignored.

Based on the measured frequency in case (c), the following steps are used to estimate the dimensional change required for new cavities:

1. The volume of the cavity is estimated to be 0.116 m^3.
2. The volume of a small port which has a diameter of 5/8” and a height of 1.7” is $8.8 \times 10^{-6} m^3$, thus sixteen ports will total $1.41 \times 10^{-4}\ m^3$. Removing sixteen small ports will make $(\Delta f)_2 = 0.11$ *MHz*. The resonant frequency is estimated to be $f_r = 351.60 + (\Delta f)_2$ 351.71 *MHz.*
3. The two big ports in the new cavities will be 102 *mm* high with diameter of 140 *mm*, increased from the 120 *mm* diameter used in the prototype cavity. This change will result in a volume increase of $8.364 \times 10^{-4}\ m^3$. Increasing the diameter of two big ports will make $(\Delta f)_3 = -0.63$ *MHz*. The resonant frequency becomes $f_r = 351.71 + (\Delta f)_3 = 351.08$ *MHz.*
4. The six 1.37” ports with a height of 1.75” to be added in the cavity covers have a total volume of $3.63 \times 10^{-4}\ m^3$. Installing them will give $(\Delta f)_4 = -0.28$ *MHz.* These ports are assumed to be covered with blank flanges. The resonant frequency will be $f_r = 351.08 + (\Delta f)_4 = 350.80$ *MHz.*

In normal operation of the cavities, maximum insertion of the plunger must be avoided. At the desired operating frequency, $f_o = 351.93$ *MHz*, the tuner plunger needs to stay at around the midpoint $d = 25$ *mm*. If the tuner is moved to the $d = 25$ *mm* position, the resonant frequency will be $f_r = 350.80 - \frac{(\Delta f)^t}{2} = 350.80 - 0.78 = 350.02$ *MHz* in the present prototype. This shows that the frequency of the prototype cavity is lower than the optimum by $\sim$ 1.9 *MHz*. Thus, new cavities must be machined with corrected dimensions to raise the frequency by 1.9 *MHz*. Note that the tunable frequency range with the plunger tuner will be $351.93 - (0.17 + 0.78) = 350.98 < f_r < 351.93 + 0.78 = 352.71$ *MHz.*

URMELT simulations show that a reduction of the cavity radius by 2.3 *mm* can raise the fundamental mode frequency by 1.9 *MHz*. The cavity dimension used in the URMELT program is shown in Table 1.

REFERENCES

[1] Basic Design for the RF System of the SPring–8, K. Nakayama, H. Suzuki, E. Minehara, and T. Harami, JAERI–M 01–012

[2] Penetration of RF Fields into Holes in Cavity Walls, R. M. Hutcheon, and R. A. Vokes, IEEE Trans. on Nuclear Science, Vol. NS–32, No. 5, October 1985

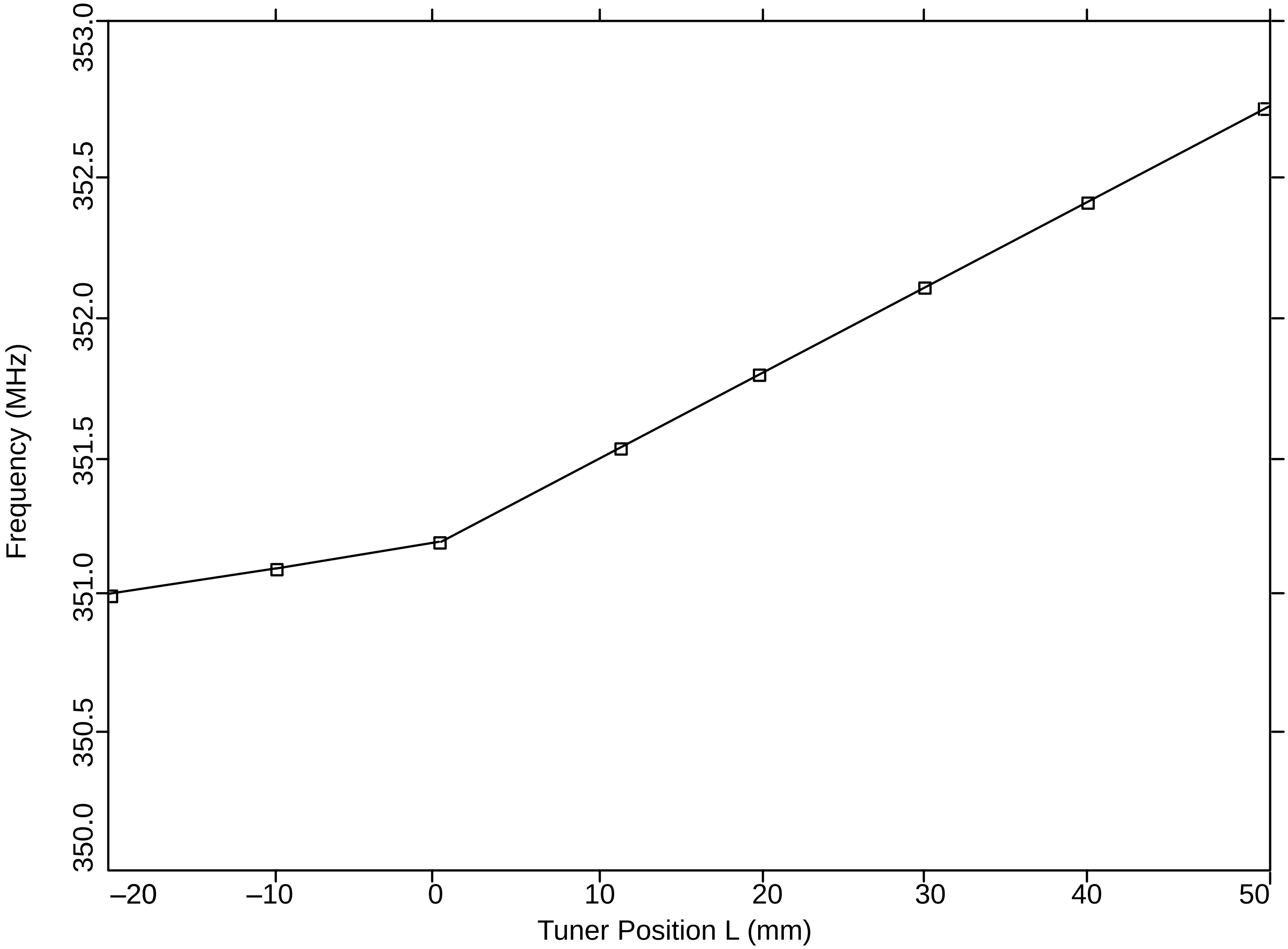

Figure 1 Storage Ring Single Cell Cavity Tuner–Frequency Characteristic

TABLE 1. URMELT code input

```
$FILE  LPLO=T LSAV=F ITEST=0 $END
$351.93 MHz SPHERICAL CAVITY
$BOUN $END
$MESH NPMAX=10000 $END
#CAVITYSHAPE
0.0
0.0000 0.0000
0.3297 0.0000
0.3297 0.0278
–1. –0.1835
0.1462 0.2113
0.1290 0.2113
–1. –0.01421
0.1162 0.2032
0.0971 0.1626
–1. +0.01421
0.0700 0.1687
0.0700 0.300
0.0400 0.4259263
0.0000 0.4259263
0.0000 0.0000
9999. 9999.
$MODE  NMODE=20 MROT=0 RWAKZ=0. FUP=2770 $END
$PLOT LCAVUS=T LMECU=T LMESH=T LFLE=T LFLH=T $END
$PRIN LER=F LEFI=F LEZ=F LHR=F LHFI=F LHZ=F
LPOWER=F LMATPR=F MODPR=6 LEZ2=F LPLE=F LPLH=F $END
```